Grant NAG 3-1148

Three-Dimensional Grid Adaptation to Geometry and Flow Solution

Final Report

Summary of Work Completed During the Period

March 8, 1990 - May 9, 1996

Prepared for

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May 6, 1996

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1.0 Introduction

The titled research has been partially supported by a research grant from the NASA Lewis Research Center under Grant Number NAG 3-1148. It was a multi-year project, initiated on March 8, 1990 and renewed annually. The total amount awarded was $175,000. In recent years, however, the support for the project from NASA Lewis has been on and off. The most recent funding was $40,000 for a one-year period from March 10, 1994 to March 9, 1995. The project period was twice extended for a total of one year to May 9, 1996 with no additional funding. Now we submit this final report to terminate the project.

This research is aimed at developing an adaptive grid generation technique for calculations of internal flow fields such as turbomachinery, inlets, nozzles, and ducts. The approach employs parametric mapping and source-influenced grid control. The method redistributes the coordinates of grid points to accommodate the characteristic features of the flow field to improve grid quality.

2.0 Achievements Made During the Funding Period

(1) Technology development:
A new grid adaptation technology was developed that is based on numerical mapping and potential theory. It improves grid quality by adapting an initial grid to various aspects of grid quality parameters to eliminate or reduce undesirable grid characteristics presented in the initial grid. Grids can be adapted to geometry, flow solution, and/or grid quality itself by the choice of defining grid control sources. The detailed descriptions of the method can be found in the published technical papers listed in the end of this report, as well as the progress reports submitted to the NASA technical officer of this project.

(2) Code development:
Both two- and three-dimensional grid adaptation codes, MAG2D and MAG3D respectively, were developed using the developed method and demonstrated with various applications. Again, details can be found in the publications and previous reports. A series of parametric study was conducted to normalize the grid control, but results indicate that it is very difficult to normalize the grid control parameters because too many parameters are involved and too often they are case-dependent. Another effort was given to develop a nonuniform parametric mapping concept to

improve the robustness of the MAG3D code, especially in handling the boundary layer region.

(3) Efficiency and capability improvement:
The MAG3D was installed with an improved search algorithm that reduces operation counts. A dramatic cost reduction was achieved by employing the coarse mesh adaptation. The grid adaptation is performed on a coarse mesh extracted from a fine initial mesh, and then the fine adapted mesh is obtained by filling the missing points using interpolation. Also, MAG3D was installed with a multi-block capability that enforces smoothness in grid distribution across block boundaries. Both abrupt changes in cell sizes and kinkedness in gridlines were removed by using grid control sources of the neighboring block in the adaptation of multi-block grids.

(4) Grid embedding:
The grid adaptation by redistribution has a limitation in the degree of adaptation, while it is advantageous in improving the quality of a flow solution without increasing the number of grid points and without a special provision in the flow solver. In order to offset this weakness, a grid embedding technique was incorporated to refine the grid locally in a region where it is needed. The approach further improves the solution accuracy without requiring a large modification in a flow solver and without a large penalty in computation.

(5) Removal of undesirable grid properties:
A reckless increase in the level of grid adaptation can cause a severe grid distortion that may hurt the convergence of a subsequent flow calculation. Also, it can degrade the grid quality near a boundary, especially when grid points on the boundary are not allowed to move. This task was performed to couple the solution-adaptive process with the grid-quality-adaptive process to remove undesirable grid properties.

3.0   Technical Papers Produced

(1) Choo, Y. K., Eiseman, P. R., Lee, K. D., "Techniques for Grid Manipulation and Adaptation," NASA Computational Fluid Dynamics Conference, Moffett Field, California, March 1991.

(2) Lee, K. D., Henderson, T. L., and Choo, Y. K., "Grid Quality Improvement by a Grid Adaptation Technique," Proceedings of 3rd International Conference on Numerical Grid Generation in Computational Fluid Mechanics, pp. 597-606, Barcelona, Spain, June 1991.

(3) Loellbach, J. M., Huang, W. C., and Lee, K. D. "Three-Dimensional Navier-Stokes Calculations using Solution-Adaptive grids," Proceedings of AIAA 10th

Computational Fluid Dynamics Conference, pp. 985-986, Honolulu, Hawaii, June 1991.

(4) Lee, K. D., Loellbach, J. M., and Kim, M. S., "Adaptive Control of Grid Quality for Computational Fluid Dynamics," Journal of Aircraft, Vol. 28, No. 10, pp. 664-669, October 1991.

(5) Lee, K. D., Henderson, T. L., and Choo, Y. K., "MAG3D and its Application to Internal Flowfield Analysis," Proceedings of NASA Workshop on Software Systems for Surface Modeling and Grid Generation, Hampton, VA, pp. 363-377, April 28-30, 1992.

(6) T. L. Henderson, W.-C. Huang, K. D. Lee, and Y. K. Choo, "Three-Dimensional Navier-Stokes Calculations Using Solution-Adaptive Grids," AIAA Paper 93-0431, 31st AIAA Aerospace Sciences Meeting, Reno, Nevada, January 1993.

(7) Lee, K. D., "Grid Quality Control in Computational Fluid Dynamics," Advances in Control and Dynamics Systems, Vol. 59, pp. 265-290, 1993.

(8) Huang, W. C., Bacon, J., Lee, K. D., and Choo, Y. K., "A Three-Dimensional Grid Adaptation Method for Navier-Stokes Solutions," AIAA Paper 94-0317, 32nd AIAA Aerospace Sciences Meeting, Jan. 1994.

(9) Bacon, J. A., Henderson, T. L., and Lee, K. D., "Grid Generation Using an Elliptic-Hyperbolic Hybrid Method," Proceedings of 4th International Conference on Numerical Grid Generation in Computational Fluid Dynamics and Related Fields, pp. 1-13, Swansea, UK, April 1994.

(10) Whitlock, M., Lee, K. D. and Choo, Y. K., "Grid Quality Enhancement Using a Grid Adaptation Method," AIAA Paper 95-2201, AIAA 25th Fluid Dynamics Conference, San Diego, A, June 1995.

(11) Chand, K. K., Lee, K. D., and Choo, Y. K., "Adaptive Grid Generation Using Redistribution and Embedding," Proceedings of the 5th International Conference on Numerical Grid Generation to CFD and Related Fields, Mississippi State, MS, April 1996.

(12) Chand, K. K., Lee, K. D., and Choo, Y. K., "Adaptation of Structured Grids with Redistribution and Embedding," AIAA Paper 96-2064, to be presented in 27th Fluid Dynamics Conference, New Orleans, LA, June 1996.